Collaborative Evaluation of the Present and Historic Sediment Dynamics of Jamaica Bay, NY (Gateway National Recreation Area)

Proposal submitted by:

S. Goodbred, R. Wilson, K. Cochran, C. Flagg*, R. Flood, H. Bokuniewicz, R. Swanson

Marine Sciences Research Center, Stony Brook University, Stony Brook, NY 11794-5000

*Environmental Sciences, Brookhaven National Laboratory, Upton, NY 11973

1. Project Overview:

This proposal comprises a collaborative effort between two research groups at the Marine Sciences Research Center, Stony Brook University. The overarching goal of the collaborative studies is to understand and quantify sediment dynamics in the Jamaica Bay estuary-marsh system as related to recent large-scale losses of vegetated wetlands. Specifically, the individual study components will (1) establish a quantified sediment budget for using a suite of natural and anthropogenic radioisotope tracers and (2) determine the system's hydrodynamics relative to pre- and post-anthropogenic alterations using quantitative circulation models. A major benefit of this combined field-modeling approach is that it allows the research group to independently verify results based on both direct, in-situ measurements and modeling outputs. The PIs of each group will work closely during the project to ensure that field efforts, sampling locations, and study results are coordinated. The remainder of the proposal text describes the goals, design, and products of the two studies, with a joint summary of milestones and interim products at the end.

2. Radioisotope Study:

Sedimentation history and budgets for the Jamaica Bay estuary-marsh system: Seasonal to decadal dynamics revealed through radiotracer studies

PIs: Steven Goodbred, J. Kirk Cochran, Roger Flood

2.1. Rationale:

Sediments in coastal wetlands and shallow estuaries are dominated by fine-grained cohesive material. However, the dynamics of these systems are difficult to successfully understand because of (1) non-linear behavior associated with fine-grained sediment cohesion, (2) biological modifications to the environment (e.g., bioturbation, plant stabilization, etc), and (3) physiochemical interactions within sedimentary deposits (e.g., role of pollutants and organics in substrate stability). In addition, studies of wetlands require a comprehensive understanding of both the marsh proper and the adjacent estuary system, because the majority of sediments delivered to the marsh surface are derived from sediment resuspension in the estuary. In this way, most creeks and estuaries provide temporary storage for new sediments, which are subsequently transported onto the marsh by a combination of waves, tides, and storms. However, the estuary must act as a net exporter of sediment, not serve as a long-term sink which commonly occurs in dredged settings. To fully consider the issues of cohesive sediments and marsh-surface accretion, quantifiable measures of sediment flux, transport patterns, and accumulation rates are needed to appropriately understand ecosystem behavior and its response to environmental changes (natural or anthropogenic). *Here we propose to use a suite of radioisotope tracers to investigate the Jamaica Bay marsh-estuary complex for (a) reconstructing a 50-100 year sedimentation history and (2) developing a comprehensive sediment budget.*

2.2. Radioisotope Study Approach:

The main approach of this investigation will entail the *use of naturally occurring radioisotopes to reconstruct sedimentation histories and patterns*. The specific radiotracer approaches are described below. In addition to the radiotracers approach, we will also acoustically image the marsh-estuary fringe *with multibeam sonar to understand mass sediment movements from marsh edge to deeper water*. Preliminary evidence suggest that slumping along dredged perimeters may be an important component of sediment movement in Jamaica Bay.

^{210}Pb and ^{137}Cs —A successful approach for studying fine-grained sediment dynamics in the coastal zone has been the use of naturally occurring radiotracers. For past several decades, ^{210}Pb (lead) and ^{137}Cs (cesium) have been used to investigate decadal patterns of sediment accumulation and transport in a variety of coastal, marine, and fluvial settings. Both radionuclides are added to coastal wetlands and estuaries principally from the atmosphere. ^{210}Pb (half-life = 22 yr) is a member of the naturally occurring ^{238}U decay series and is produced in the atmosphere from decay of ^{222}Rn that has emanted from rocks and soils. The decrease in ^{210}Pb activities down core, coupled with the known rate of decay, provide a means for determining sediment accumulation rates over about 5 half-lives or 100 years. In contrast, ^{137}Cs (half-life = 30 y) is produced as a consequence of nuclear fission and its principal input to the enviroment has been through the atmospheric testing of atomic weapons. This input peaked in 1963 as a consequence of the Nuclear Test Ban Treaty and this peak input of ^{137}Cs is used as a marker horizon to determine time scales of sediment accumulation. Thus ^{137}Cs provides mean accumulation rates over approximately the past 40 years of sediment accumulation. We have used ^{137}Cs an in index of sediment accumuation in the Grassy Bay basin of Jamaica Bay, and elsewhere (Cochran et al. 1998). The Grassy Bay core, collected in 2002 and compared with cores collected by Bopp and colleagues in 1982 and 1988 (Bopp et al. 1993), showed that the ^{137}Cs peak was present about 27 cm deeper than in 1988, suggesting a sediment accumulation rate of 1.9 cm/y. This rate agrees well with that estimated from the depth of the ^{137}Cs peak in the core (1.6 cm/y) and from the earlier estimates by Bopp et al. (1993). Thus, both ^{137}Cs and ^{210}Pb serve to determine sediment accumulation patterns over the past decades, a period over which significant changes in sediment input and estuary configuration have been made by human development.

^{7}Be and ^{234}Th —The decadal resolution of ^{210}Pb and ^{137}Cs is not sufficient to investigate seasonal to annual scales of sediment mobility within coastal environments. This is important because such seasonal to interannual periods encompass the synoptic-scale forcing of coastal processes, such as storms, wind events, runoff, and river discharge. To investigate this dynamic scale of coastal behavior, researchers have applied naturally occurring short-lived radiotracers, such as ^{7}Be (beryllium) and ^{234}Th (thorium). Applications have ranged from estuaries, river mouths. Outlined below are a brief descriptions of the unique aspects of ^{7}Be and ^{234}Th and their benefits for the proposed study.

^{7}Be and ^{234}Th have half-lives of 53 and 24 days, respectively. In the natural environment, these radioisotopes can be detected for roughly five half-lives, or about 4-8 months. This monthly timescale makes them ideal for studying recent sedimentation patterns and highfrequency processes that occur over days to months. Such temporal resolution is very important, because it is fine enough to capture event-driven and seasonal sedimentation patterns that others cannot, but it is also sufficiently time-averaged so that synoptic events are not missed entirely nor over weighted. ^{7}Be is produced in the atmosphere by the interaction of cosmic rays with atmospheric gases and is delivered to the marsh-estuary system through precipitation, runoff, and dry deposition. In contrast ^{234}Th is produced in seawater by the decay of dissolved ^{238}U (uranium). ^{234}Th is thus delivered to the marsh-estuary solely by mixing with seawater through the inlet. This dual source for the radionuclides make them ideal for tracing sediment inputs from both terrestrial (^{7}Be) and marine (^{234}Th) sources. Therefore, the proposed study can distinguish between sediment delivered via runoff and that from a seaward source.

Both ^{7}Be and ^{234}Th are strongly particle reactive and bond tightly with sediments in the water column, making them excellent tracers for sediment movement. The radiotracer approach also allows sediment accumulation to be tracked both through the estuary and on the marsh surface, so that sediment dynamics in subtidal habitats and high marsh environments can be studied in a comprehensive manner. Finally, the input of ^{7}Be and ^{234}Th to the estuary can be directly measured using an atmospheric fallout trap and direct seawater measures, respectively. Based on these direct input measures, quantified sediment budgets can be determined from the radioisotope activities measured in the lab. Thus, results can be compared with modeled transport predictions and incorporated into hydrodynamic models.

Multibeam sonar — In addition to the radiotracer surveys, we will also conduct a state-of-the-art multibeam sonar survey of the Jamaica Bay estuary. The multibeam echosounder is an effective mapping technique that transmits a narrow sound beam perpendicular to the ship track and records the time and strength of the returned sound. Because orientation of the sonar transducer and the angle of the sonar beams is precisely known, both bottom characteristics (e.g., grain size, shells, vegetation) and bathymetry can be determined. The depth information and signal strength then are used to construct a digital terrain model (DTM) and a backscatter image of seafloor reflectivity. We believe this will be an important component of the study, because one of the factors contributing to subsidence of the marsh surface and loss of material at the outer edges may be slumping and failure of the banks. Failure is likely to occur because the marsh edges have been oversteepened through dredging and/or erosion. Results from a similar setting with deep channels along marsh edges (i.e., Tuckerton marshes) reveal numerous slump blocks that also appear to change over time indicating an active process. Creek-bank slumping and erosion have also been linked to the rapid loss of marshes in Venice lagoon (e.g., Day et al., 1998). This could be a major mechanism for sediment redistribution in Jamaica Bay, and we plan to address this process to reach better constraints on our radiotracer-derived sediment budgets and sedimentation histories. Furthermore, the high-resolution multibeam data will enable us to locate ideal coring sites that provide a relatively uniform seafloor and avoid areas of disturbance or sand waves.

2.3. Radioisotope Study Design:

The radioisotope portion of the proposed study will consist of (a) seasonal research cruises to collect samples, (b) intensive gamma-ray spectroscopy to measure radioisotopes after each cruise, and (c) lab analyses to convert measured radioisotope activities into sediment fluxes, accretion maps, and accretion histories. It is anticipated that seasonal cruises will be conducted to determine seasonal and interannual variations in sediment accumulation and redistribution. At least one cruise will occur toward the end of the winter storm season (March), and at least one cruise will occur in late summer to capture the period of marsh-plant production and more quiescent coastal conditions (September). For each cruise shallow sediment cores will be collected at about 100 sites throughout Jamaica Bay, including channels, basins, creeks, and marsh surfaces. The location of each site will be recorded using differential-GPS and reoccupied on subsequent cruises.

All samples will then be measured for radioisotope activities at MSRC s Radioisotope Lab, using planar gamma detectors that are ideally suited to simultaneous ^{7}Be, ^{234}Th, ^{210}Pb and ^{137}Cs measures. Only one sample per day can be counted on each instrument, so all four gamma detectors are needed to process the large number of samples required for a detailed sediment budget (ex., 100 samples 4 detectors = 25 days ¯ 1 ^{234} Th half-life). Because ^{7}Be and ^{234}Th have short half-lives, we will use an inventory approach (i.e., integrated downcore activity, dpm/cm^{2}) that requires only one sample per site, thus maximizing the spatial coverage. Measurements are not as urgent for longer-lived ^{210}Pb and ^{137}Cs, and so we will be able to measure multiple downcore samples to establish a high-resolution activity profile (2-5 cm increments). We expect to analyze these more detailed cores at 5-10 sites per cruise.

A group of sediment sample will also be analyzed for grain size, bulk density, and organic content. Grain size measures will be made using an automated settling tube for the sand fraction and a Sedigraph 5100 X-ray size analyzer for the mud fraction. In addition to sedimentological interpretations, these values will be used to normalize radioisotope activities for grain-size effects. This will allow us to make a basinwide comparison of results (i.e., between sandy and muddy sites). Bulk density and organic content will be measured by oven drying and muffle combustion, respectively. Bulk density is a good proxy for the erodability of sediment deposits, and organic content reflects the percentage of non-mineral matter contributing to accretion rates. The atmospheric flux of ^{7}Be will be measured between cruises using a wet/dry fallout trap set up at Jamaica Bay. ^{234}Th flux will be derived from known seawater concentrations and salinity-based mixing curves.

The multibeam-sonar survey will be conducted in the first year before the radioisotope investigation. This will allow general bottom bottom habitats and sediment types to be identified and thus, the best sampling sites for radioisotope work can be selected. Data will be collected with the tranducer (sound source) mounted both in its traditional downward-facing orientation, as well as using its side-looking ability to directly image the channel banks. Mapping results will be presented as a series of seafloor maps showing sun-illuminated bathymetry with 5-cm accuracy and acoustic backscatter as a proxy for sediment character and bottom roughness.

3. Modeling Study

Present and historic hydrodynamics and sediment dynamics of Jamaica Bay estuary

PIs: Robert Wilson, Charles Flagg, Henry Bokuniewicz, R. Lawrence Swanson

3.1. Modeling Objectives

The overall project goal is to determine whether anthropogenic physical alterations to the pre-developed Jamaica Bay have modified the bay s hydrodynamics and thereby its sediment dynamics so that its wetlands are no longer able to be naturally maintained. We have defined the following objectives first, *for contemporary bathymetry* and second *for historical bathymetry:*

1. Description of sediment transport patterns within the bay
2. Quantitative description of horizontal sediment fluxes throughout the bay
3. Quantitative description of sediment accumulation rates and patterns of accumulation of throughout the bay
4. Evaluation of the physical processes controlling sediment transport, resuspension, and deposition in different segments of the bay.

We define as a final objective an evaluation of the changes in items 1-3 above from historical to contemporary settings, and an interpretation of these changes in terms of changes in bay hydrodynamics. Hydrodynamic features which we might consider include tidal current structure, tidally induced and density induced and residual current structure, asymmetry in both tidal currents and tidal elevation, bed shear stress, lower layer salt intrusion and its relationship to water column stratification, vertical mixing and particle trapping.

3.2. Modeling Approach

Our approach is to apply a calibrated 3-D hydrodynamic model to a description of both the present and historic hydrodynamics and sediment dynamics. We propose to use a newly available 3-D numerical circulation model which is especially well suited for simulations of hydrodynamics and material transport processes in complicated estuarine geometries. The model is referred to as the Finite Volume Coastal Ocean Model (FVCOM) (Chen, Liu and Beardsley, 2003); it is a 3-D primitive equation sigma-coordinate ocean circulation model that includes the Mellor-Yamada level 2.5 turbulent closure. The model has wetting and drying capabilities. It is unique in that it uses an unstructured grid; this allows for a significantly better representation of the complex geometry of Jamaica Bay than can be achieved by 3-D finite difference model such ECOM-si (HydroQual, 1998) which uses a curvilinear grid. FVCOM has a module for the transport of suspended sediment which is based on similar resuspension and depositional physics to that used in ECOMSED (HydroQual, 2002).

The figure below shows an example of an FVCOM model grid for Jamaica Bay using *contemporary* NOS bathymetry augmented with recent observations provided by Roger Flood of the Marine Sciences Research Center. It provides insight into the resolution achievable using an unstructured grid. The grid was constructed using the commercial gridding software SMS Version 8.0. Our *historic* soundings were collected by the USCGS during 1877 and 1878. The soundings in Rockaway Inlet were updated in 1879.

Hindcast simulations would be performed for existing bathymetry such as that shown above. These simulations would require time series *observations* for surface heat flux, surface momentum flux, fresh water inflow, boundary sea level and boundary temperature and salinity. These forcing fields would permit us to describe the response of both hydrodynamics and sediment dynamics to variability in the forcing with time scales ranging from tidal and diurnal, to synoptic and fortnightly, and monthly and longer. For simulations using historical bathymetry, we would expect to use climatologies developed for required forcing fields rather than observations.

Results from preliminary FVCOM simulations for tidal and fresh water forcing only illustrate a number of important points. Examples presented below are for neap tide simulations with an elevation amplitude of 0.4 m specified on the open boundary, a constant fresh water inflow

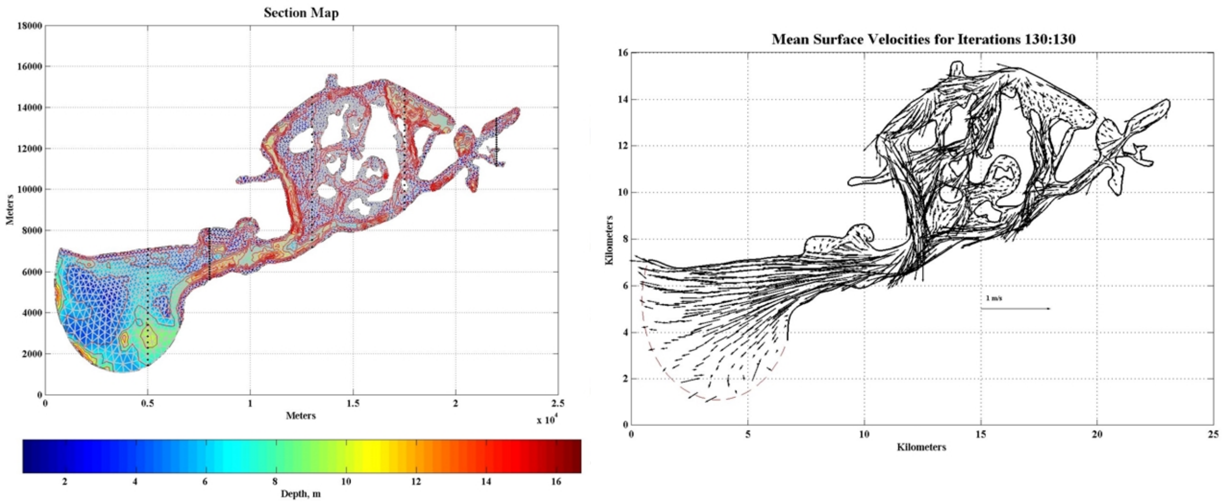

Fig. 1. Left frame shows FVCOM grid for Jamaica Bay with bathymetry [dotted black lines locate velocity and salinity sections in Fig. 2]; Right frame shows simulates surface velocity vectors during maximum ebb.

totaling 5 m^3/s distributed along the north shore of the basin, no surface heat of momentum flux and no wetting or drying:

1. Tidal currents and associated bottom shear stress are spatially complex.
2. There is well developed depth dependent estuarine circulation in several arms of the basin.
3. There is significant haline stratification throughout much of the basin.
4. There is strong inter-tidal variation in salinity, haline stratification, and vertical mixing in much of the basin.

A number of these features were evident in observations described by Gordon et al. (2002). These preliminary results give us every reason to expect that we can produce simulations with very good skill and high spatial resolution with FVCOM.

4. Research Linkages:

The radiotracer and modeling studies proposed here are both stand alone, but there are major benefits to gain from their combined approach. First, the radiotracer study will determine the rates, patterns, and distribution of sediment accretion/erosion within the marsh-estuary system. This is critical to understanding the system's overall sediment budget relative to the deficit in marsh-surface accumulation. However, the radioisotope study cannot directly account for mechanisms of transport and their relationship to estuarine circulation. Herein lies strength of the proposed modeling study, which will evaluate sediment transport pathways based on physical circulation. Thus, the two approaches are complementary, providing both process (modeling) and product (radiotracers). Furthermore, each study provides groundtruthing for the other, whereby non-linear transport behavior that the model cannot fully account for is otherwise determined using the radiotracers. Conversely, transport pathways and mechanims that can only be inferred

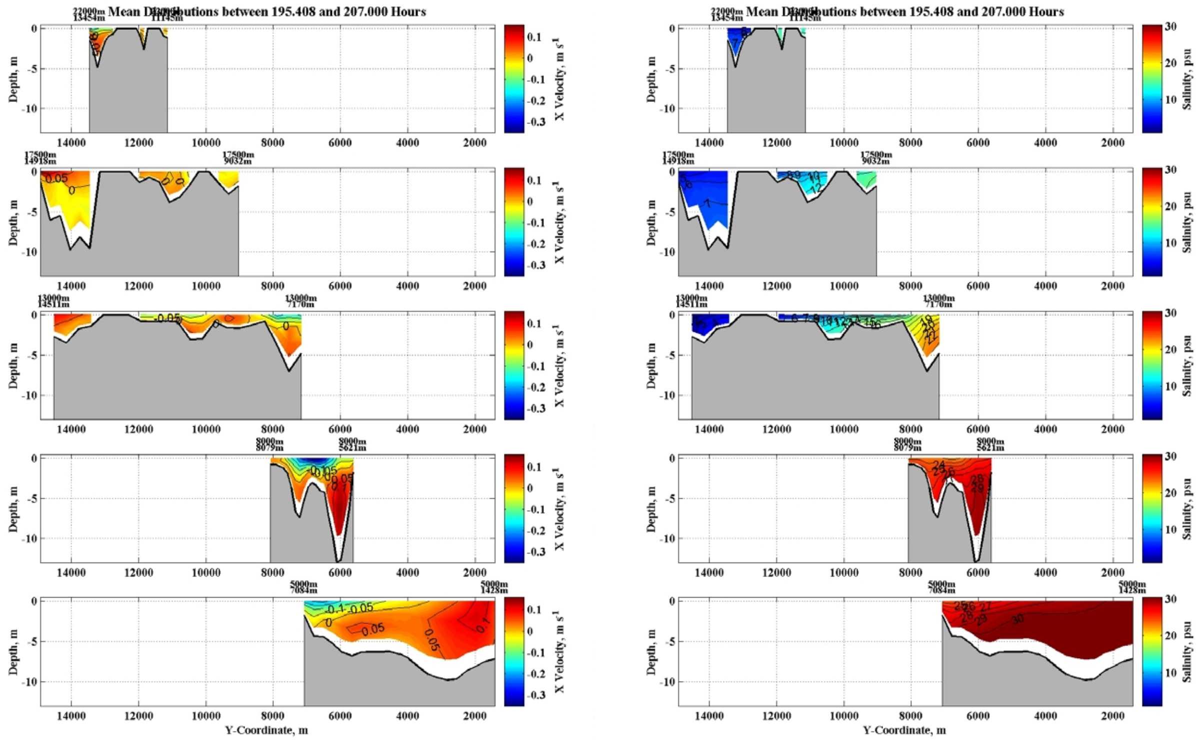

Fig. 2. Tidal residual east-west velocity (left), and salinity (right) at sections located in

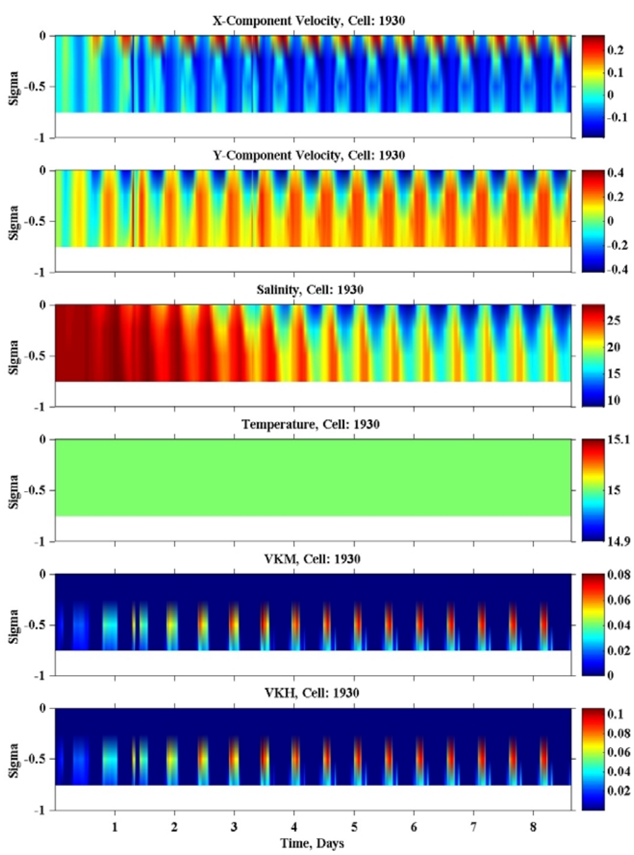

Fig. 3. Time series of vertical structure for east-west and north-south velocity components, salinity, vertical eddy viscosity and vertical eddy diffusivity at a cell near the eastern end of Rockaway Inlet showing intra-tidal variability.

from the radiotracers are revealed in the modeling study. In terms of restoring Jamaica Bay marshes, the radiotracer study will determine whether the current volume of mobile sediments could be sufficient for marsh stabilization (given altered hydrodynamics). The modeling study can then suitably forecast how modifications to Jamaica Bay bathymetry would redistribute this mobile sediment in favor of marsh accretion.

Finally, the proposed radiotracer study links very well with ongoing SET efforts by NPS researchers (C. Roman). ^{7}Be and ^{234}Th reflect sediment dynamics on the same timescales as the SET measurements (i.e., seasonal to annual) and together can serve to integrate shallow stratigraphic/land-surface dynamics with sediment transport and accumulation patterns. Specifically, the SET data alone cannot resolve individual signatures of accumulation, erosion, and subsidence. Thus, additional techniques such as glitter horizons or radioisotope geochronology are needed. Presumably marker horizons have already been emplaced, and the proposed short-term radiotracer study will add to this accretion/erosion database. Furthermore, ^{7}Be:^{234}Th ratios will also allow us to determine the general source of recently deposited sediments, thus comprising another beneficial link between the SET and radiotracer studies.

5. Products and Schedule

5.1. Study Products:

Specific products related to the radioisotope study:

1. Map of sedimentation zones and non-accretional or erosional areas for estuarine, creek, and wetland environments.
2. Calculated total volume of mobile sediments within the estuary, indicating the pool of sediments available for transport onto the marsh surface by waves, tides, and storms.
3. Short-term sedimentation rates for all sites in estuarine, creek, and wetland habitats.
4. Seasonal and interannual variations in sedimentation patterns at all sample sites.
5. Relative inputs of sediment from marine and terrestrial sources.
6. Historic (50-100 yr) sediment accretion rates and patterns in basins and marshes.
7. High-resolution map of seafloor bathymetry, bottom type, and bank failures.

Specific products related to the modeling study:

1. Description of sediment transport patterns within the bay for both contemporary and historical bathymetry
2. Quantitative description of modeled horizontal sediment fluxes throughout the bay for both contemporary and historical bathymetry
3. Quantitative description of modeled sediment accumulation rates and patterns of accumulation throughout the bay for both contemporary and historical bathymetry
4. Evaluation of the physical processes controlling sediment transport, resuspension, and deposition in different segments of the bay

General products of overall collaborative study:

1. Final Report providing detailed description and discussion of results and findings from radioisotope and modeling studies.
2. Section of Final Report that discusses differences and similarities between results of the radioisotope and modeling studies.

5.2. Project Schedule

(* = product due to NPS office)

9/03 - Joint field visit to Gateway/JB with NPS staff
- *Formal study plan due Nov. 1, 2003 for technical review
- Purchase of gamma detectors and lab preparation for sample processing
- Conduct seafloor mapping with multibeam system and produce preliminary map
- Inventory available bathymetry, topography, and model forcing data gaps required for model grid development.
- Identify specific modeling scenarios to be considered and initiate grid development and hydrodynamic modeling.

3/04 - Finalize study plan and sampling sites based on technical review and seafloor map
- First radioisotope sampling cruise and subsequent lab analyses
- Model grid refinement in light of seafloor mapping results.
- Hydrodynamic model evaluation
- Initiate sediment transport modeling

9/04 - Radioisotope sampling cruise and lab analyses
- Reconcile model and radioisotope deposition patterns
- Refine radioisotope sampling accordingly
- Refine model grid and forcing accordingly
- *Yr-1 Progress Report due Nov. 1 with preliminary radioisotope and modeling results

3/05 - Radioisotope sampling cruise and subsequent lab analyses
- Reconcile model and radioisotope deposition patterns
- Refine radioisotope sampling accordingly
- Refine model grid and forcing accordingly

9/05 - Radioisotope sampling cruise and subsequent lab analyses
- Synthesize model and radioisotope results to define sediment transport patterns
- *Yr-2 Progress Report due Nov. 1 with initial sediment budget and modeling results

3/06 - *Draft Final Report due April 1 for peer review

9/06 - *Final Report due to NPS before Sept. 1, 2006

6. References

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7. Budget and Justification

7.1. Budget Worksheet

	Year 1	Year 2	Total
Personnel			
Principal Investigators	23,000	19,000	42,000
Project Assistant	2,500	2,500	5,000
Graduate Students	40,500	36,000	76,500
Fringe Benefits	7,810	7,200	15,010
SUB-TOTAL	73,810	64,700	138,510
Other			
Equipment	60,487	0	60,487
Travel	1,000	1,000	2,000
Supplies	4,870	4,870	9,740
Subaward to C. Flagg	23,000	23,000	46,000
Ship time	10,000	10,000	20,000
Multibeam Fees	16,500	0	16,500
SUB-TOTAL	115,857	38,870	154,727
TOTAL DIRECT	189,667	103,570	293,237
MTDC	129,180	82,570	211,750
IDC @ 15% MTDC	19,377	12,386	31,763
TOTAL REQUEST	**209,044**	**115,956**	**325,000**
UNIVERSITY MATCH	60,426	0	60,426

7.2. Budget Justification

SALARIES AND WAGES: In Yr-1 a total of 3.0 mos. summer salary is requested among the 6 Stony Brook PIs (Goodbred, Wilson, Cochran, Flood, Bokuniewicz, and Swanson). In Yr-2 a total of 2.5 mos. summer salary are requested for this same group. Goodbred and Wilson will each serve as lead-PI on the respective radioisotope and modeling studies and also provide overall project administration. A small salary of 0.5 mos. support is requested for a project assistant who will aid in coordinating the field studies and multiple PIs and students. Fringe benefits on all salaries are calculated at published university rates.

Salary is also requested to support two graduate students on this project. Twelve months of stipend are requested per student per year. It is anticipated that one student each will be dedicated to the radioisotope and modeling studies. In addition, an extra 3 mos. graduate support is requested in Yr-1 for a student to complete the seafloor mapping effort. Close collaboration between the PIs and students will ensure a well-integrated final product.

PERMANENT EQUIPMENT: Funds are requested to purchase several planar gamma detectors needed to analyze the large number of radioisotope samples necessary for developing a detailed sediment budget. Based on this importance of these instruments to the MSRC research as wella s this NPS project, the University has agreed to a 1:1 match for purchasing the instrument package. Total estimated cost of the gamma systems is about $121,000, of which $60,426 will be matched by the Stony Brook Office of the Vice-President for Research (see attached letter from Gail Habicht). Requested commitment from NPS is $60,488.

TRAVEL: $1000 is requested each year to cover the costs of travel from Stony Brook to Jamaica Bay during the intensive field effort (20 x $50).

SUPPLIES: $5000 is budgeted per year for expendable supplies. Most of this money will go to the liquid nitrogen required to run the gamma detectors (~$500/week). Other relevant field items include the costs of sampling equipment and containers, such as core tubes, core caps, and plastic sleeving, and sample bags. Relevant lab items include radioisotope standards and X-ray film.

SUBAWARDS: One month of salary and overhead are requested each year for PI Charles Flagg to participate in the modeling study. Dr.Flagg is a research scientists at Brookhaven National Laboratory and he has extensive experience in modeling and will contribute significantly to the proposed study.

SHIP TIME: Funds are budgeted for use of Stony Brook's R/V Pritchard to collect the sediment samples during the two planned cruises per year. About 10 days are budgeted in each year for the two cruises, expected to take 5 days each.

MULTIBEAM FEES: Funds are requested for 5 days of multibeam seafloor mapping in Jamaica Bay ($16.5k). The daily multibeam costs for the MSRC-owned and operated EM3000 cover basic software and hardware assuming 46 operational day per year. Primary expenses include Ocean Mapping Group SwathEd software package ($25k/yr) and hardware updates and maintenance ($20k/yr), plus remobilization costs and technician time.